The Transient Radio Universe

High energy astrophysics with radio all-sky monitors

Rob Fender (University of Southampton)

In association with Transients Key Science Projects at LOFAR, ASKAP and MeerKAT

"..as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns - the ones we don't know we don't know.."

In transients there are **known knowns** (e.g. SS 433) and **known unknowns** (e.g. new black hole transients) but it is maximising the chances of finding the **unknown unknowns** that is the most exciting prospect

Widely reported as:

Wise man says stupid thing / *Stupid man says stupid thing*

In fact its :

Stupid man says wise thing

Known knowns and known unknowns: Two flavours of transients

Incoherent synchrotron emission

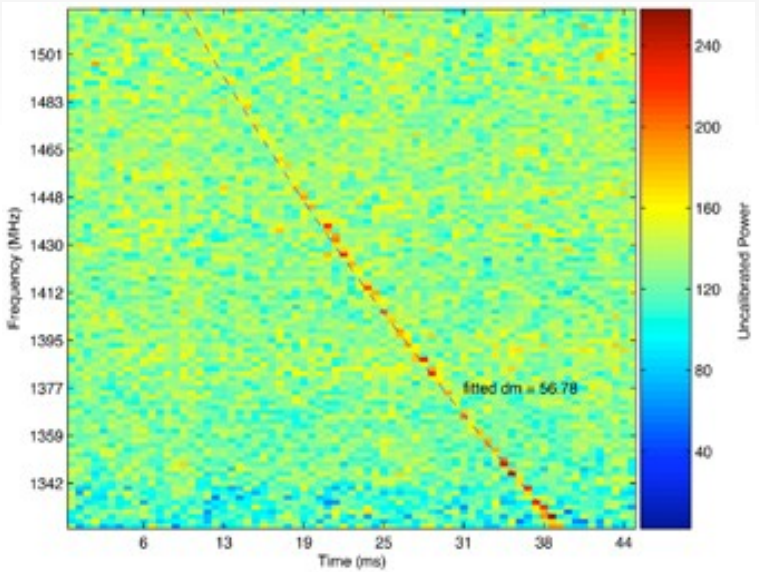
Relatively slow variability
Brightness temperature limited
Associated with all explosive events

Find these (mostly) in images

Early branch in classification pipelines

Coherent emission

Relatively fast variability
High brightness temperature
Often highly polarised



Find these (mostly) in time series

Synchrotron emission

(GHz facilities – EVLA, eMERLIN, ATA, APERTIF, MeerKAT, ASKAP)

All cases of explosive injection of energy into the ambient medium result in particle acceleration and/or an amplification of the local magnetic field → synchrotron emission.

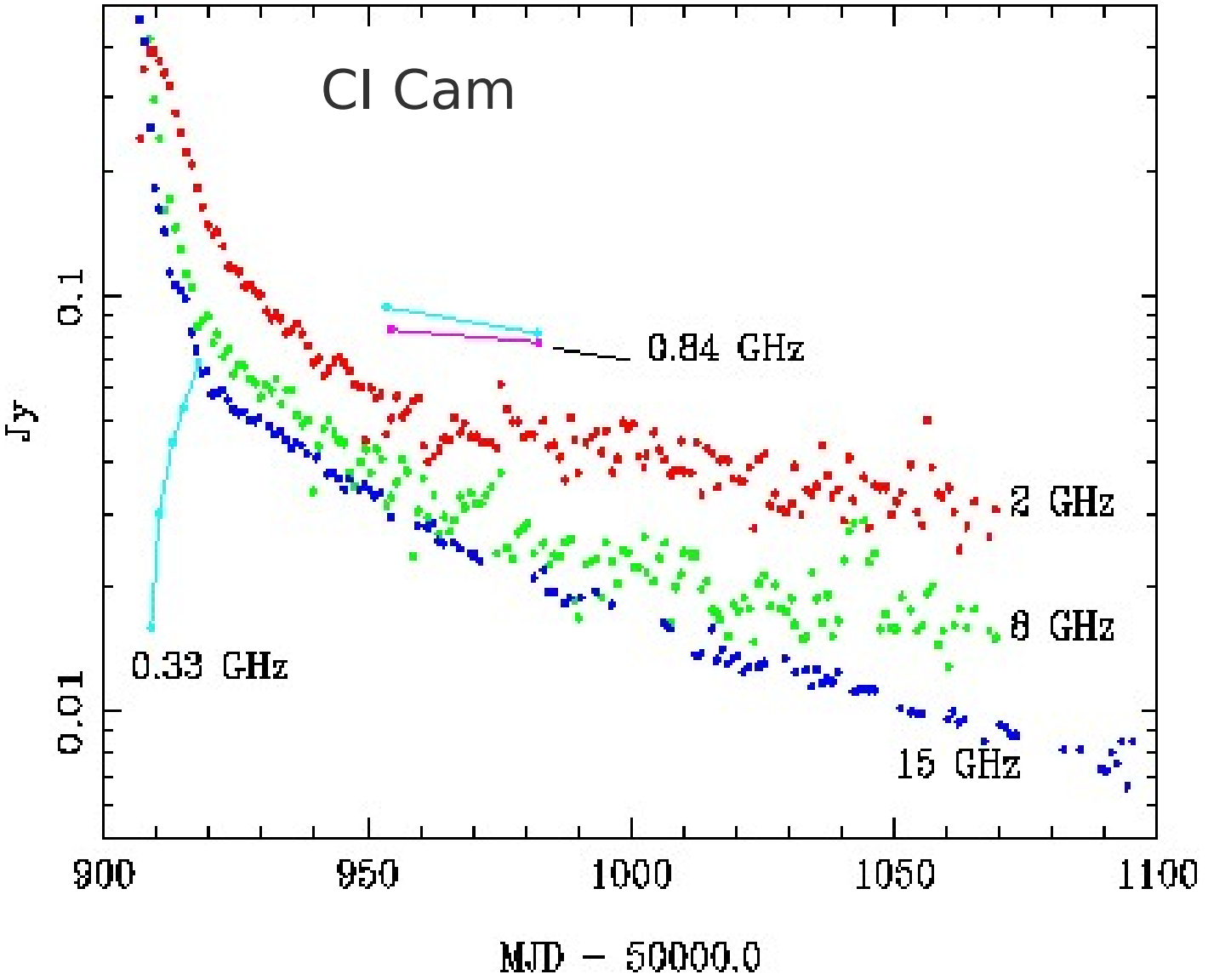
Examples of these include

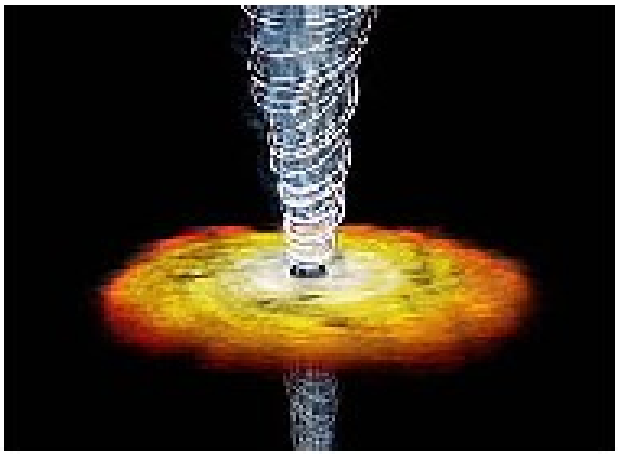
(i) Relativistic jets from X-ray binaries ('microquasars') / AGN

(ii) Supernovae and GRB afterglows

(iii) Giant outbursts from magnetars

Well established multiwavelength communities for such objects – usually associated X-ray and optical activity. However, limited to $B_T \leq 10^{12}$ K and affected by self-absorption at low freq.





Explosive particle acceleration in GRB afterglows, microquasar jets, supernovae → long-lived low-frequency synchrotron emission

→ Time-resolved census of particle acceleration in nearby universe

→ **BUT** low frequencies not optimum for early warning

Coherent emission

(MHz facilities – LOFAR, MWA, LWA, phase I SKA-low)

Resulting from the coherent movement and emission of radiation by electrons

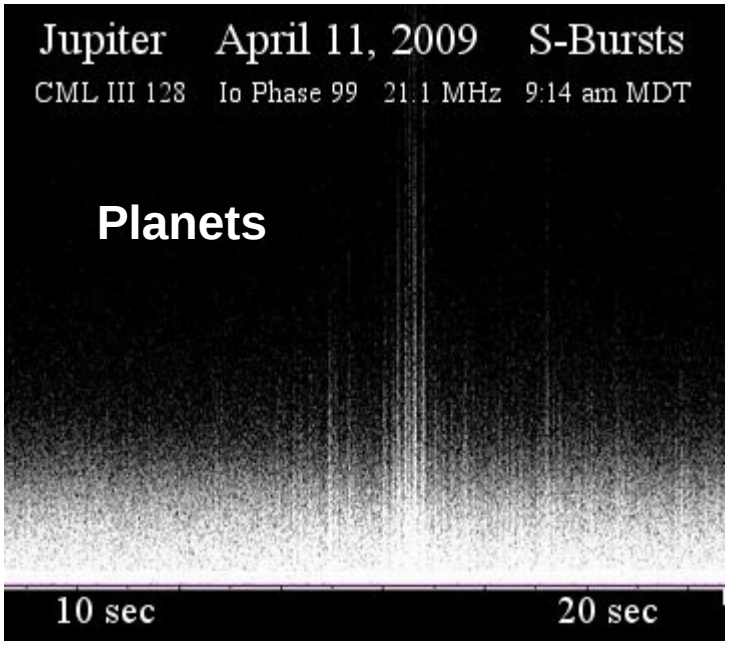
Examples of these include

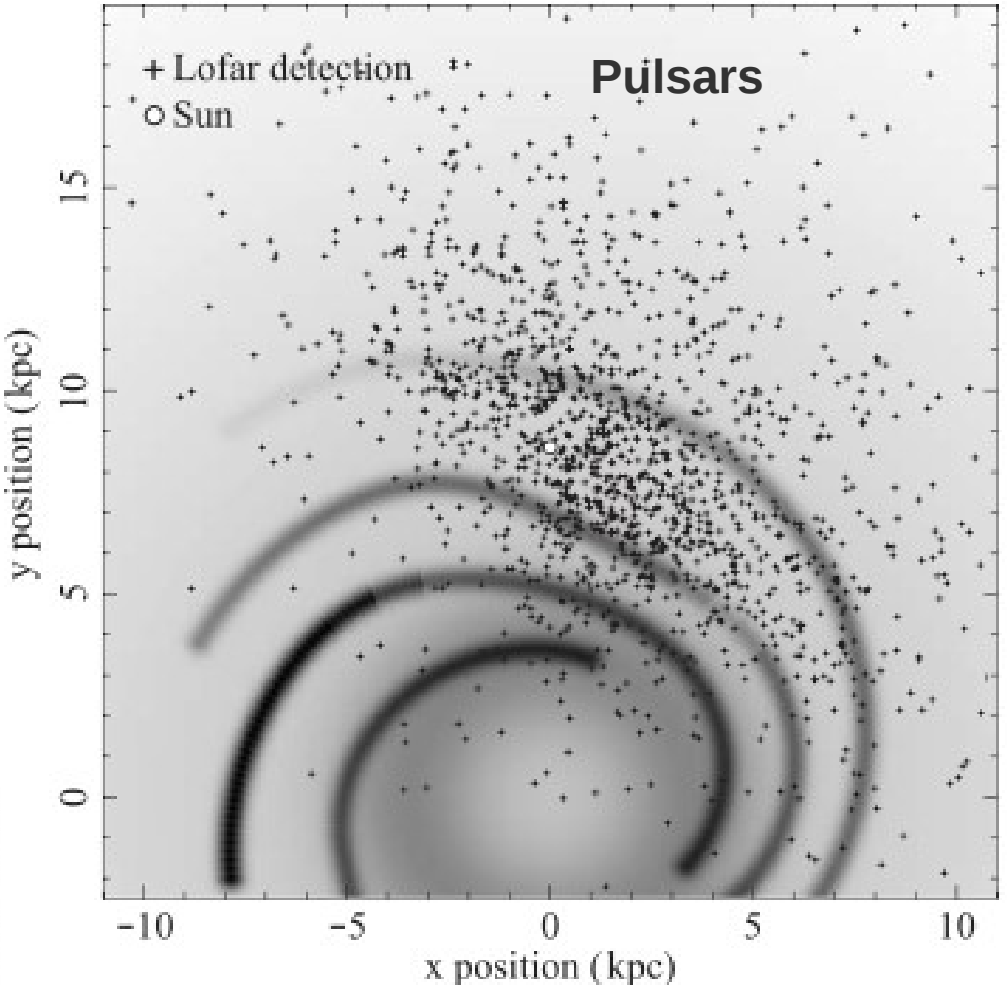
(i) Pulsars and friends (RRATs etc)

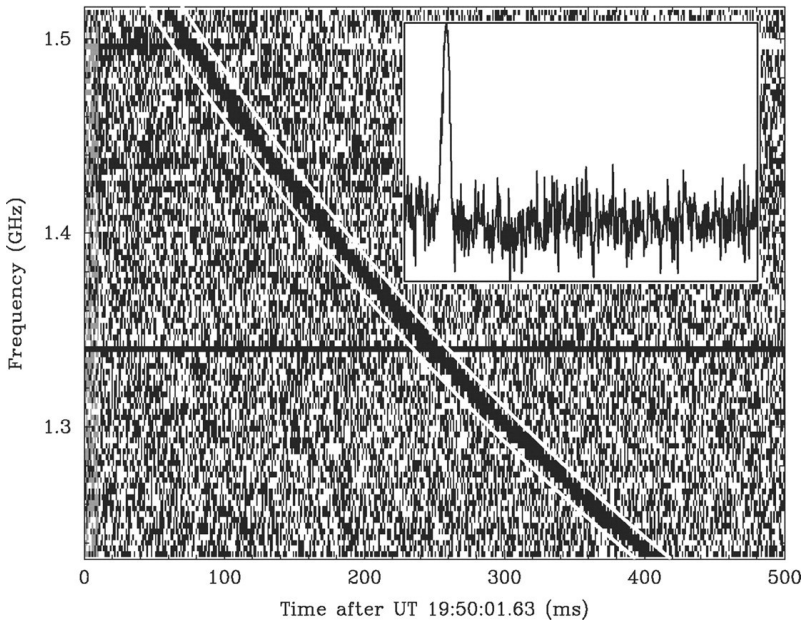
(ii) Flare stars / Planets / cyclotron masers

(iii) Who knows ?

These can have extremely high brightness temperatures and usually rise steeply at low frequencies → very exciting area for exploration with LOFAR / SKA aperture arrays

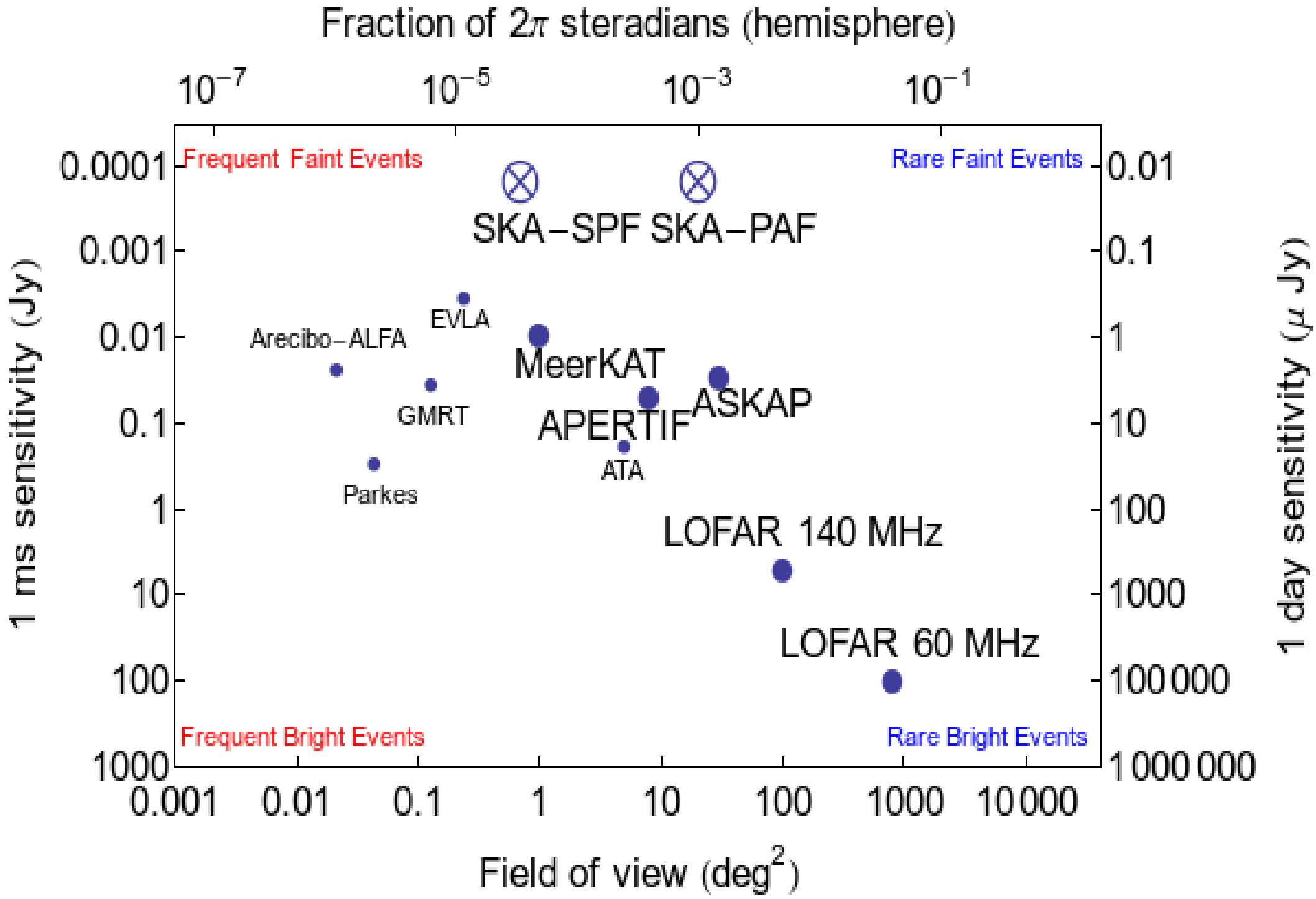




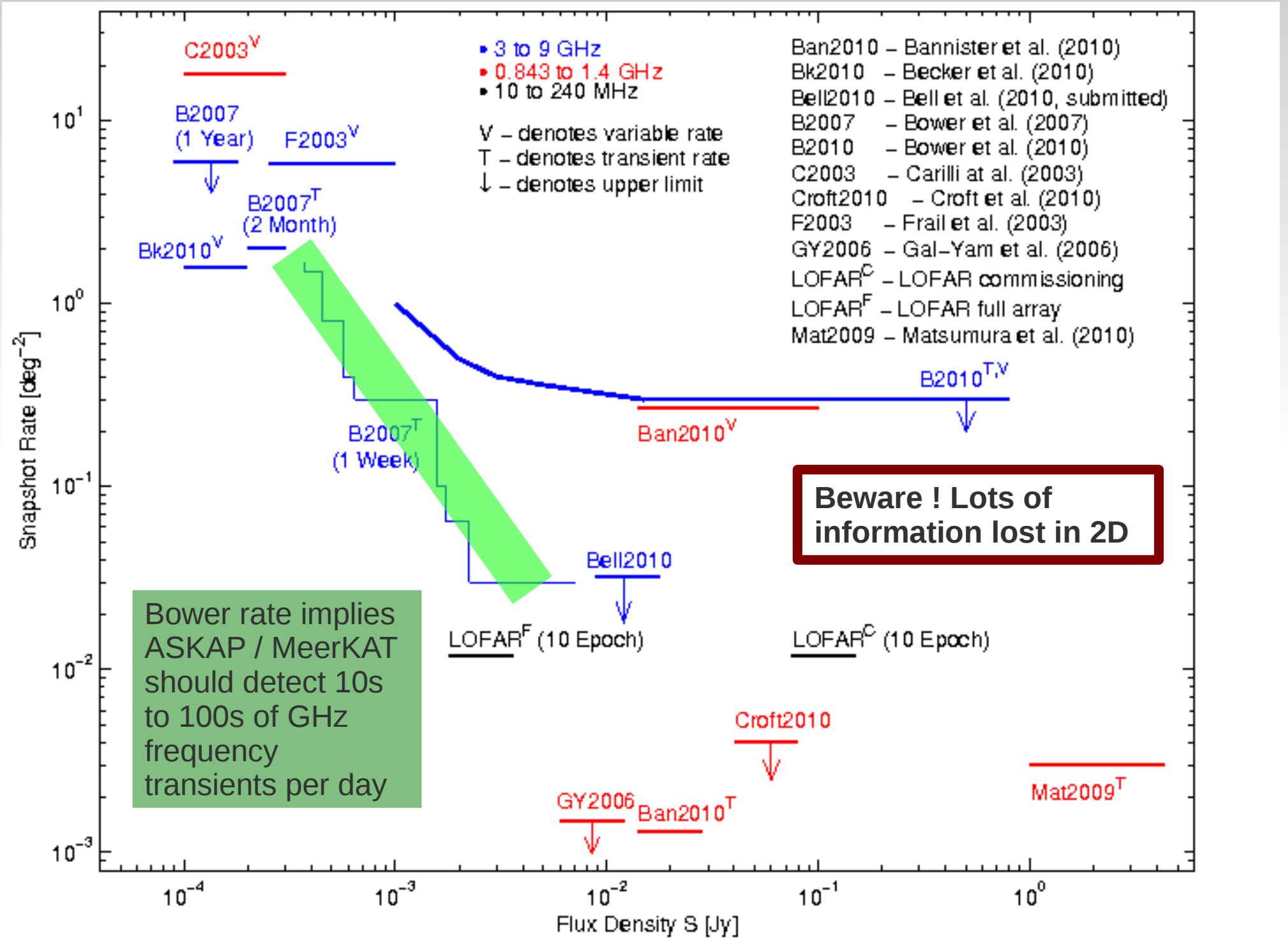


- Coherent bursts from large distances ?
- Possibly probe IGM back to EoR ?
- Associated with Adv. LIGO events ?

Transients with the new generation

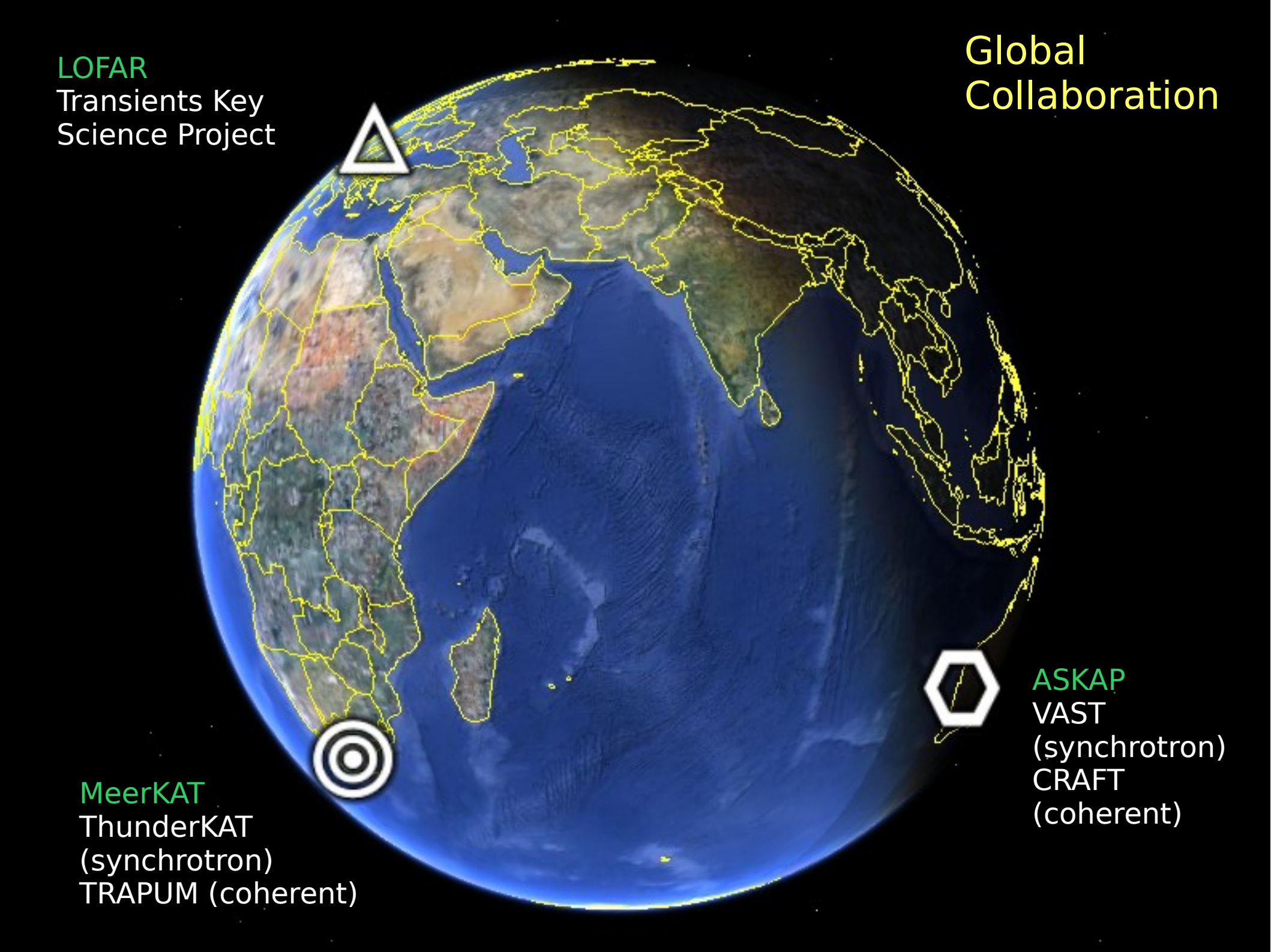


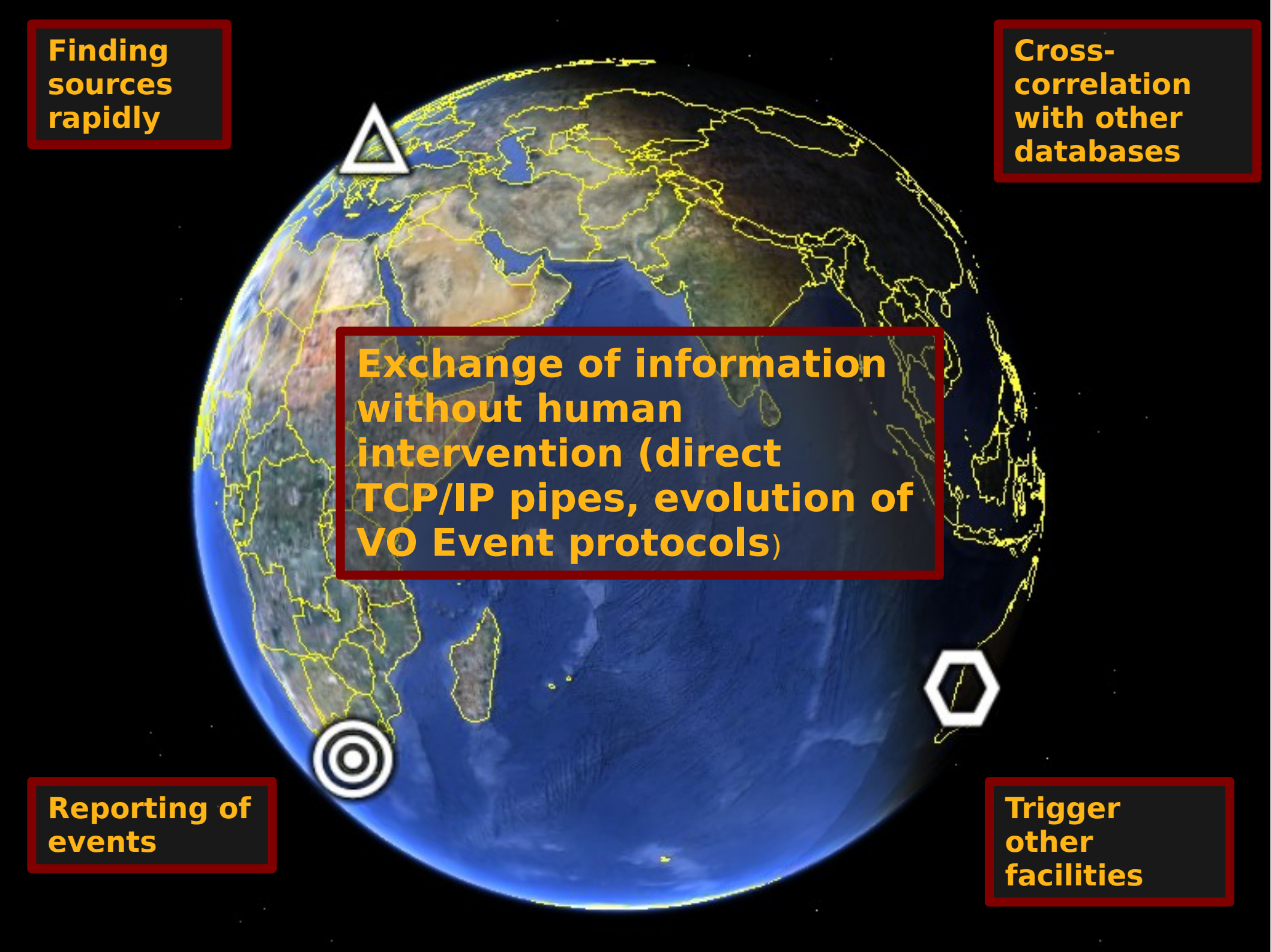
Detections / limits transient numbers: the state of the art (Bell et al.)

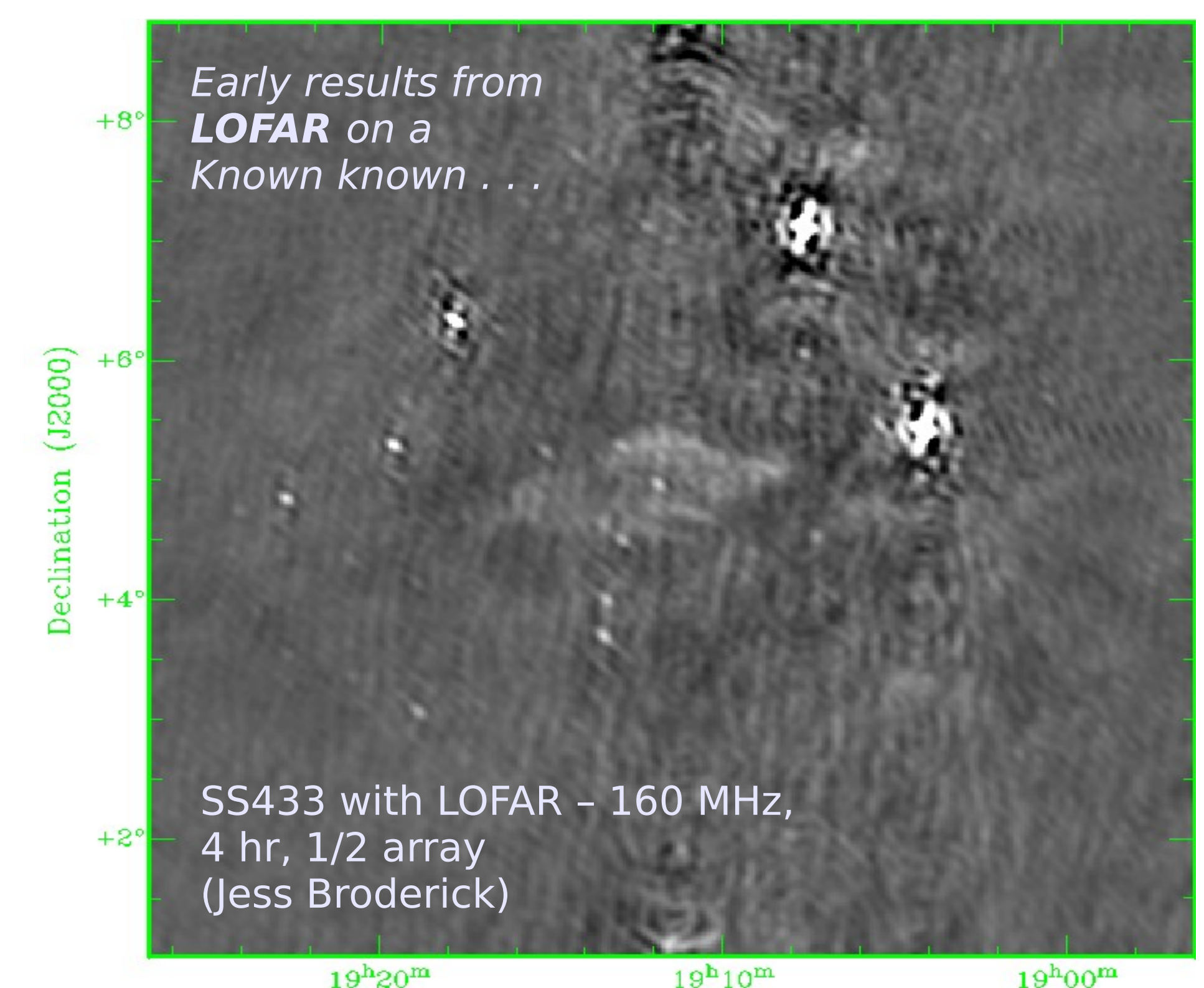


Beware ! Lots of information lost in 2D

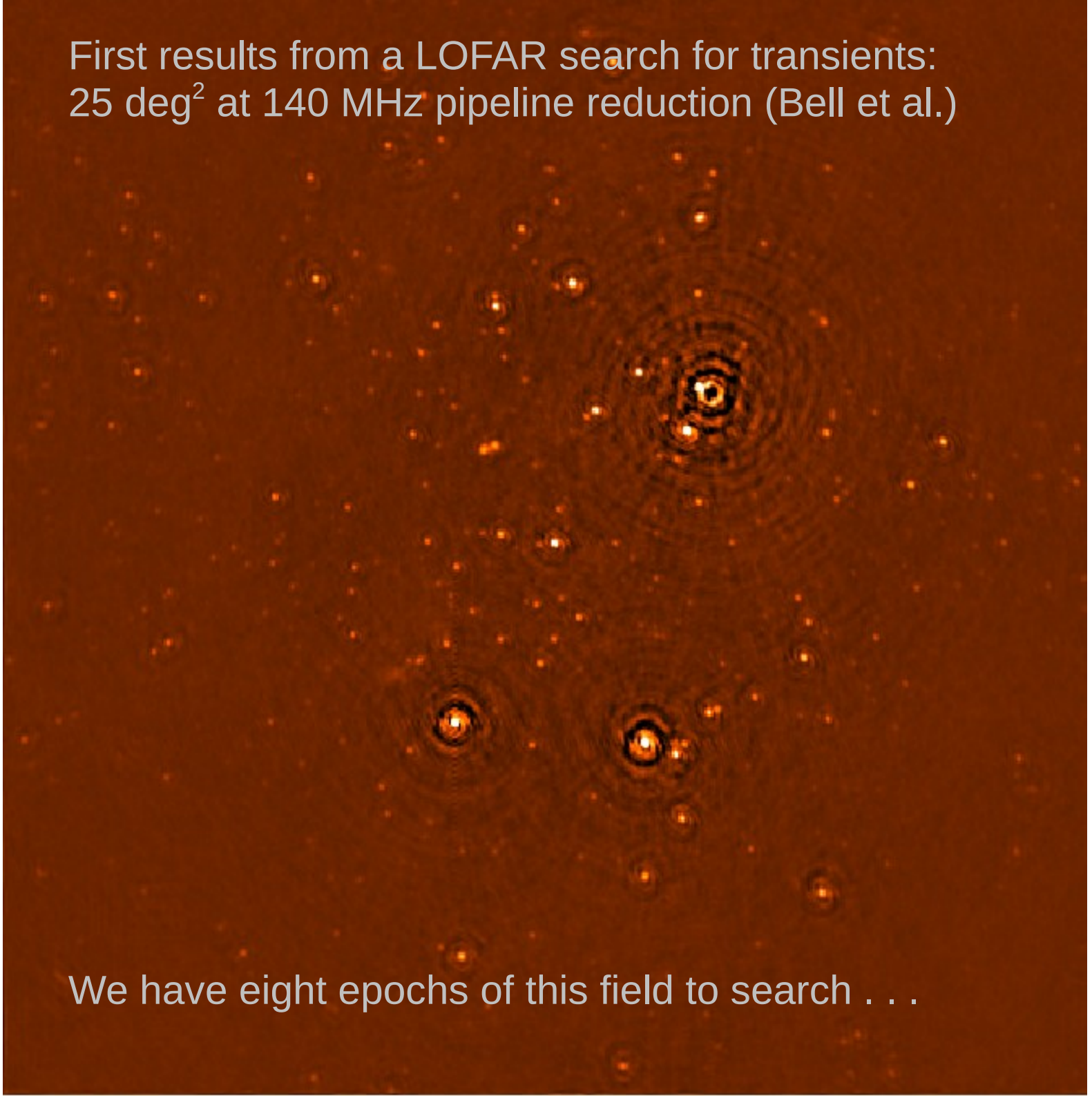
Bower rate implies ASKAP / MeerKAT should detect 10s to 100s of GHz frequency transients per day


LOFAR
Transients Key
Science Project
Global
Collaboration
ASKAP
VAST
(synchrotron)
CRAFT
(coherent)
MeerKAT
ThunderKAT
(synchrotron)
TRAPUM (coherent)


Finding sources rapidly
Cross-correlation with other databases
Exchange of information without human intervention (direct TCP/IP pipes, evolution of VO Event protocols)
Reporting of events
Trigger other facilities


Early results from
LOFAR on a
Known known . . .
+8°
+6°
+4°
+2°
Declination (J2000)
19h20m
19h10m
19h00m
SS433 with LOFAR – 160 MHz,
4 hr, 1/2 array
(Jess Broderick)

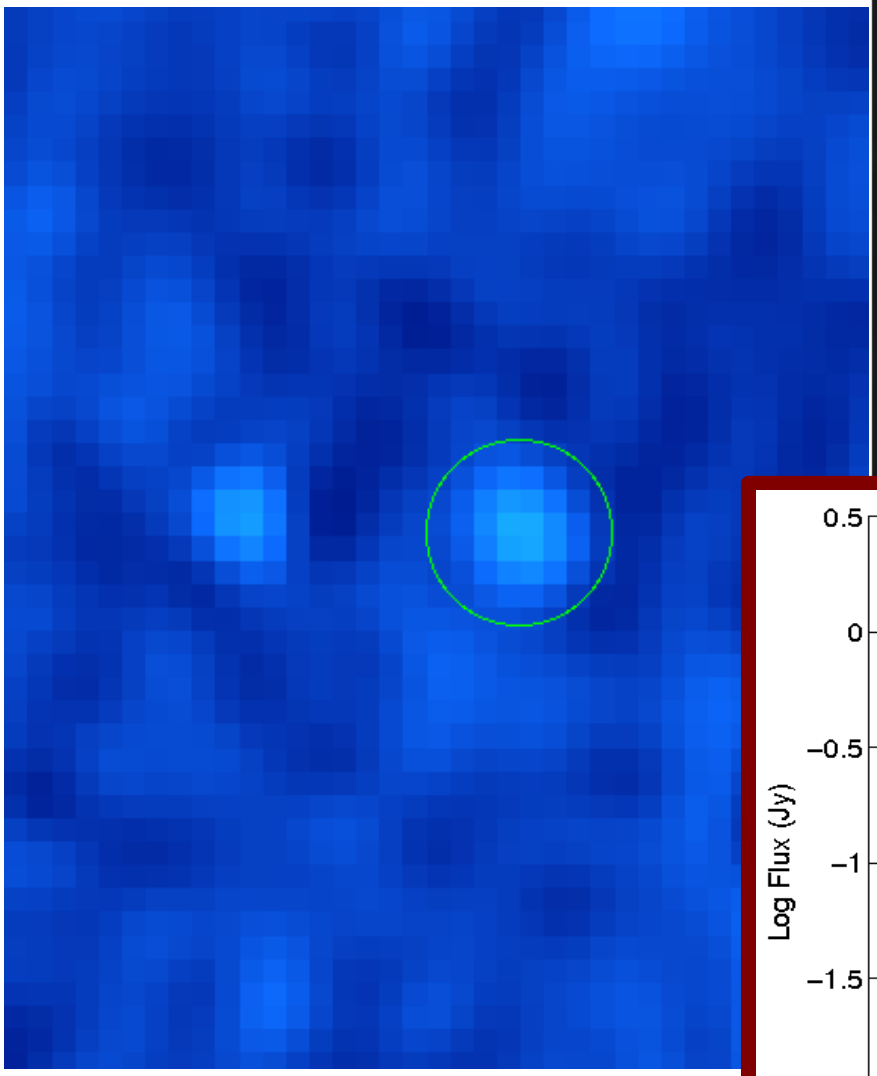
First results from a LOFAR search for transients:
25 deg^2 at 140 MHz pipeline reduction (Bell et al.)

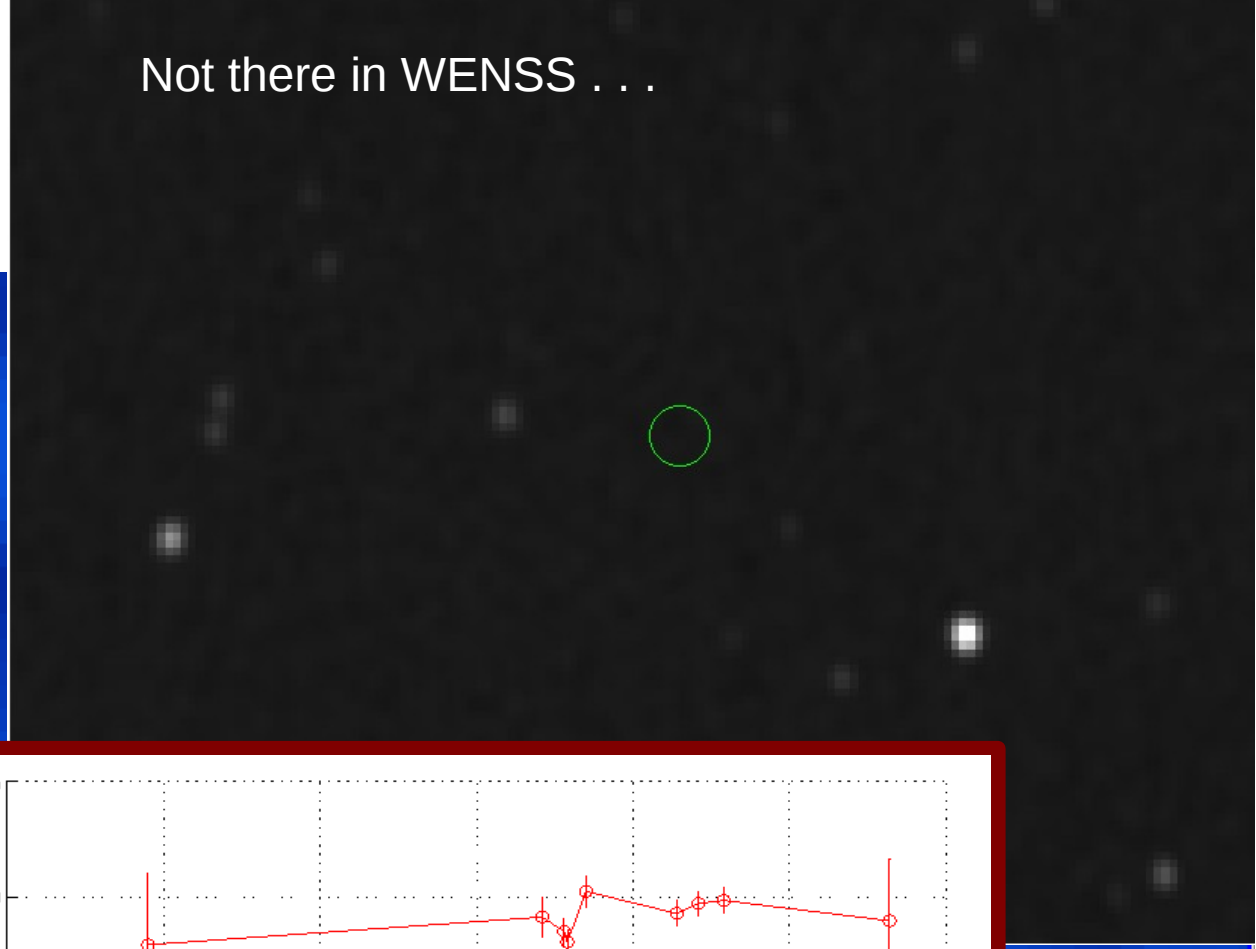


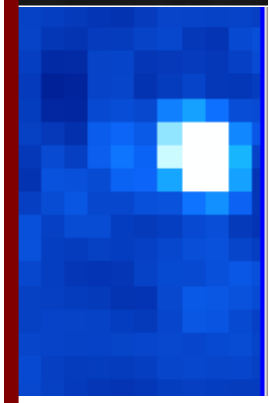
We have eight epochs of this field to search . . .

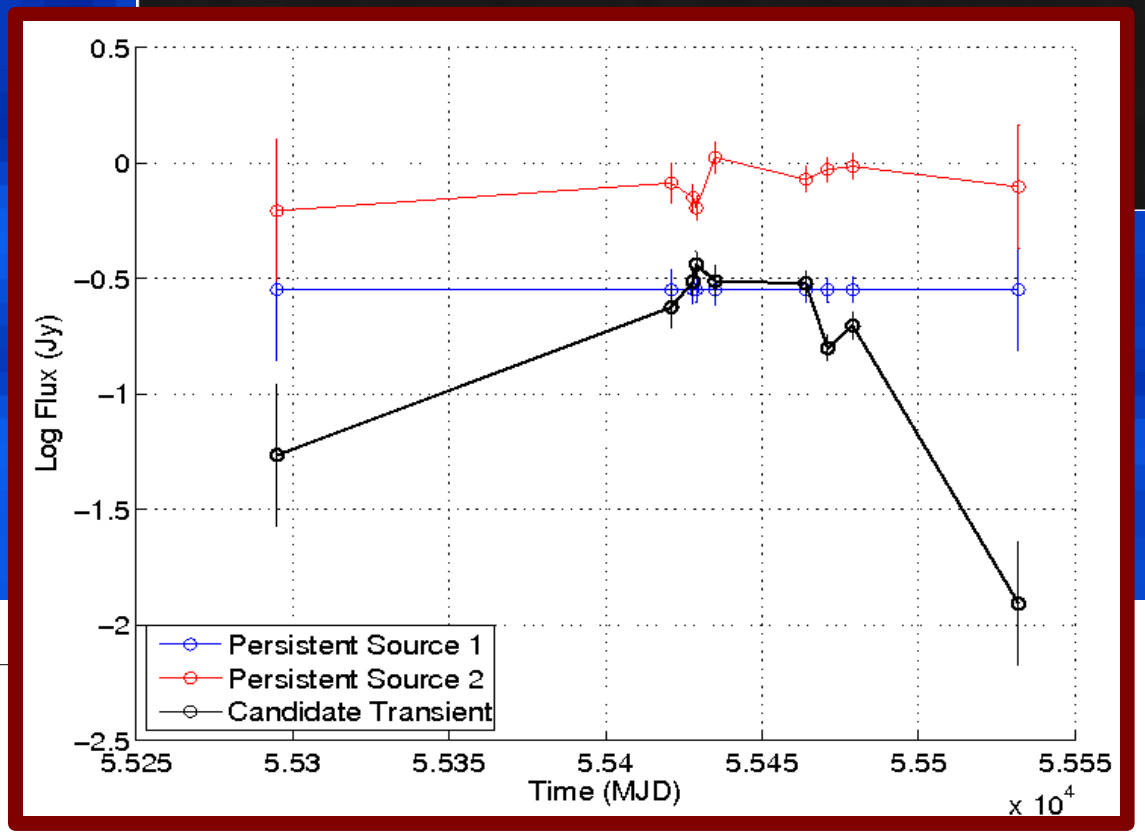
Possible first LOFAR transient ! (Bell et al.)

Not there in WENSS . . .





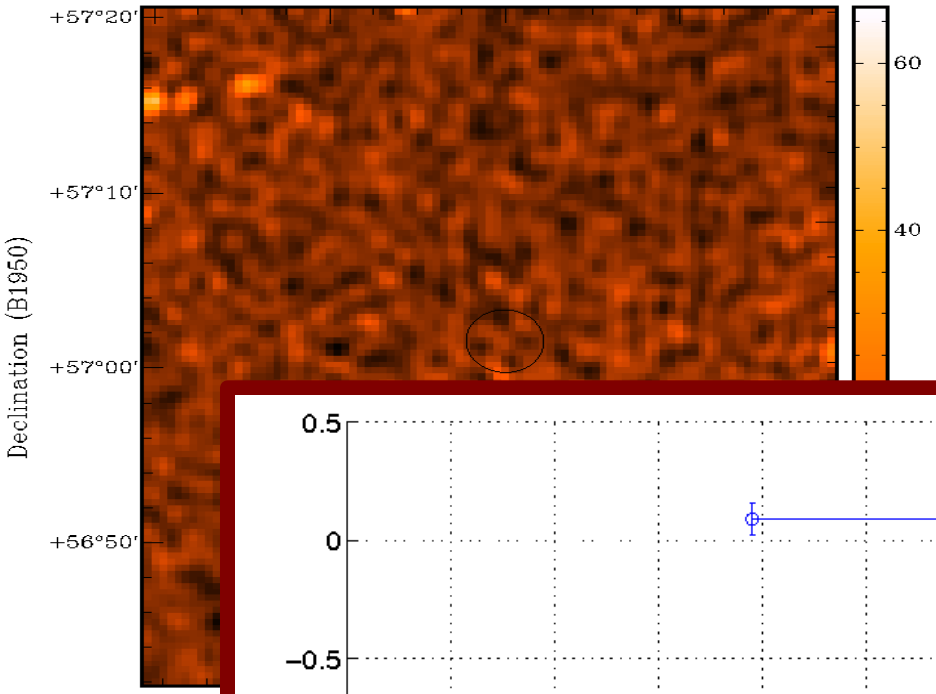


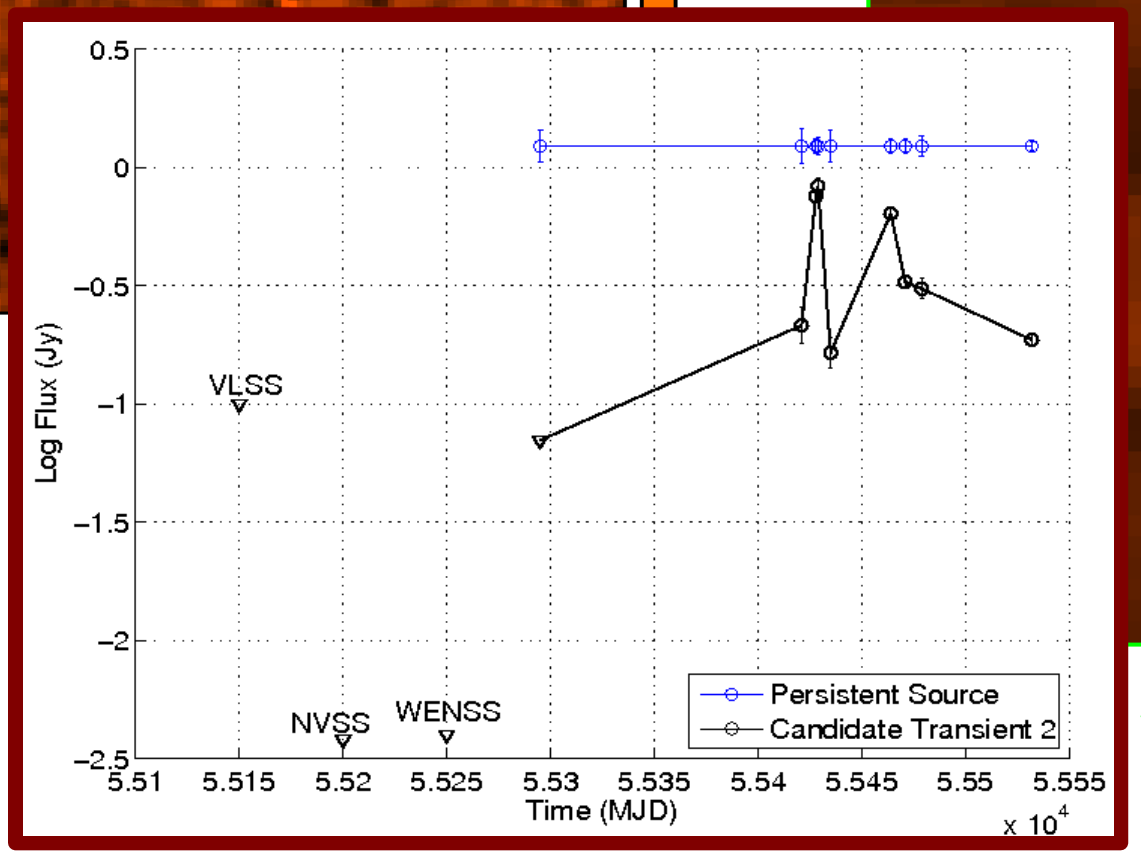


~30 arcmin

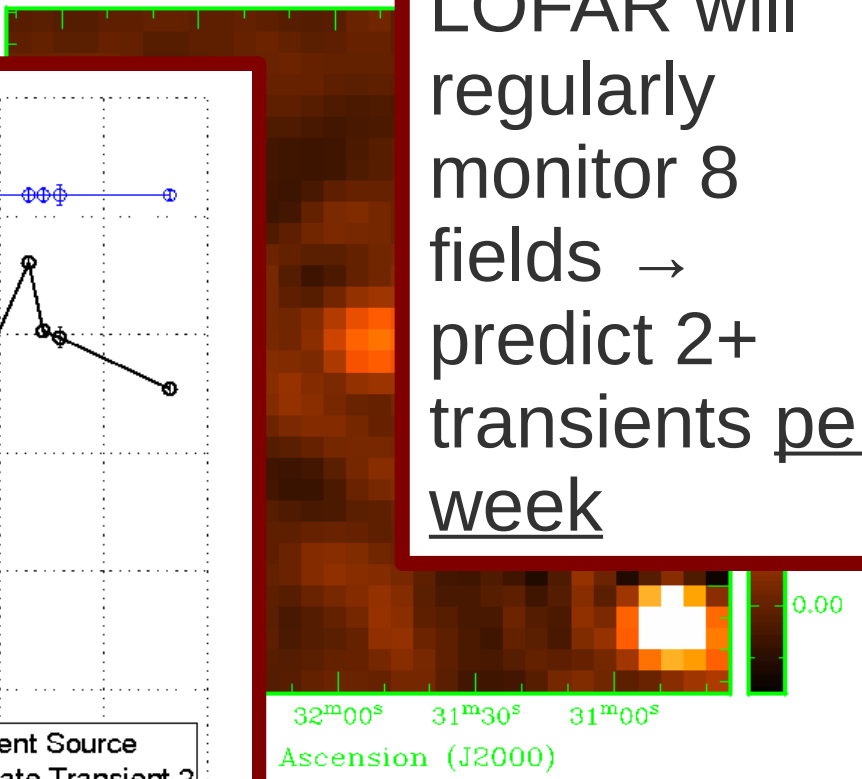
And another . . .

Second transient detected in same field. Peak flux density >0.1 Jy, **still active**.



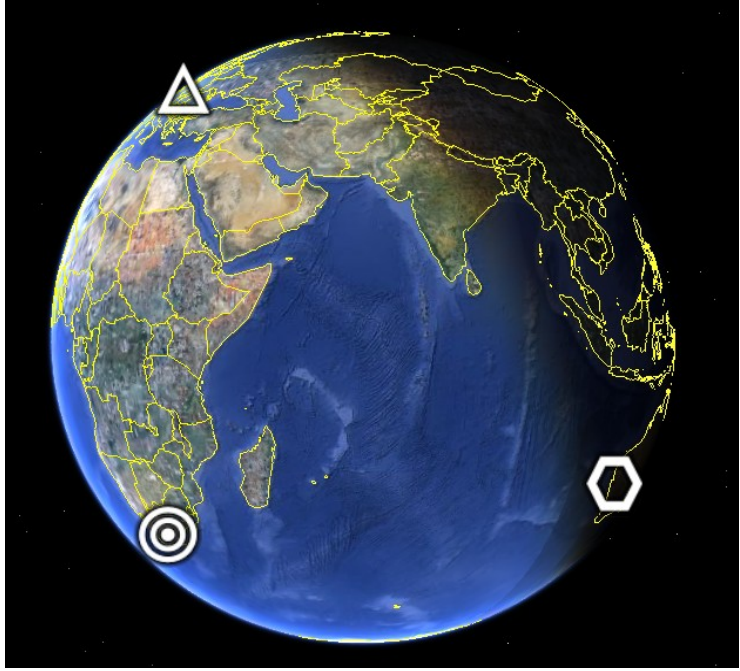


In 2011 LOFAR will regularly monitor 8 fields → predict 2+ transients <u>per week</u>



LOFAR

Timelines



LOFAR commissioning 2011
Full 'production' operations 2012+
KSP time 2012-2016

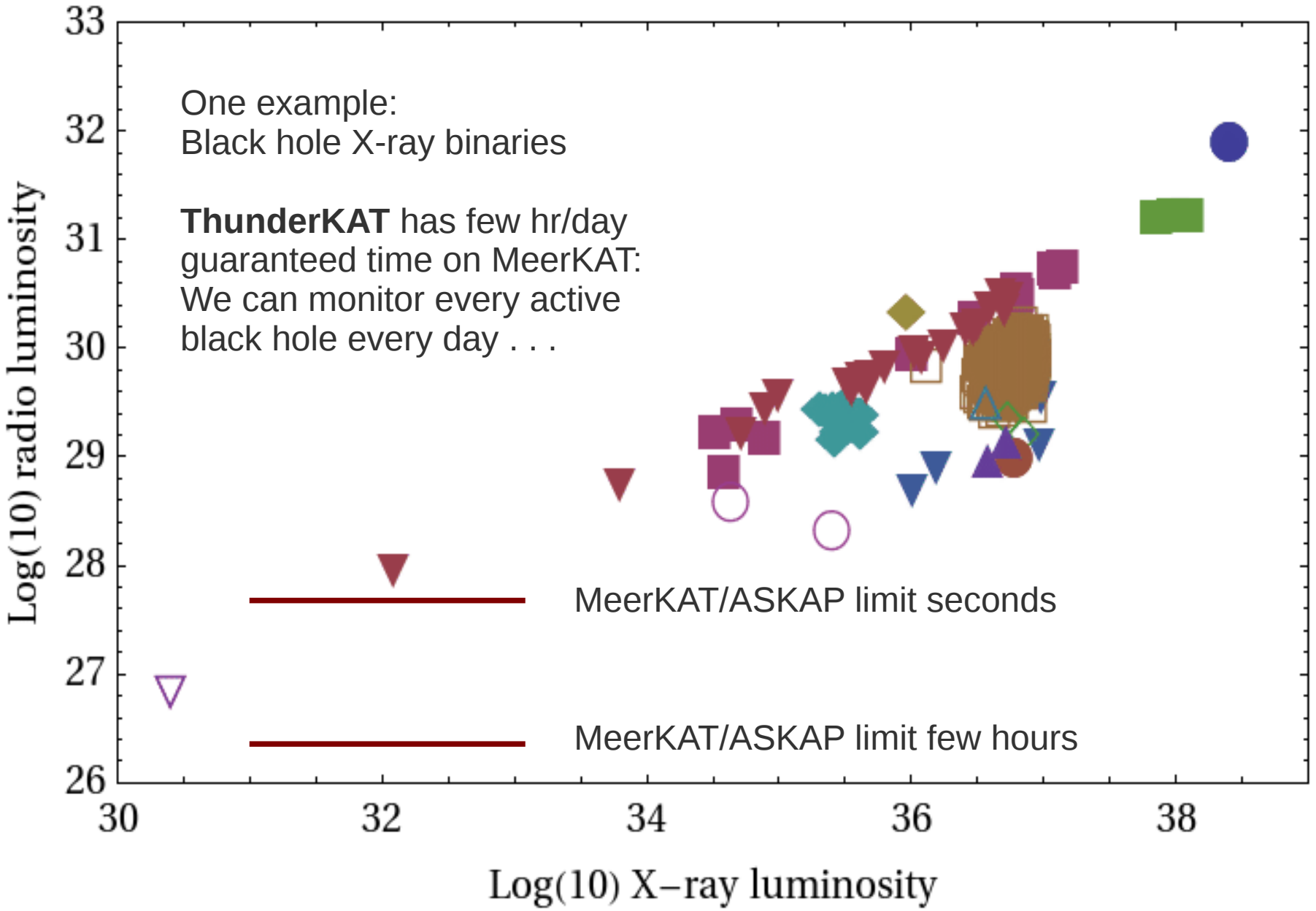
MeerKAT and **ASKAP** test arrays 2011-2013
Full array commissioning 2013+

Site selection ~2013

SKA1 ~2015

SKA ~2020 (~2025 for high-frequency extension)

What will MeerKAT and ASKAP do for us ?



Summary

Radio Astronomy is undergoing a massive expansion.

New facilities have huge fields of view, extremely rapid response and revolutionary software developments – multiple fields, lookback etc. Perfect for transients.

In all of these facilities, Transients science has been given a high priority ('key science'). Large teams have formed, latest technologies and communications embraced, multinational and multiwavelength collaborations born (e.g. MoUs signed with HESS, LIGO/VIRGO, PS1, LT...).

What kind of X-ray mission works best for us ? **All sky-monitors** and/or **rapid follow-up capabilities** provide the best synergy for us.